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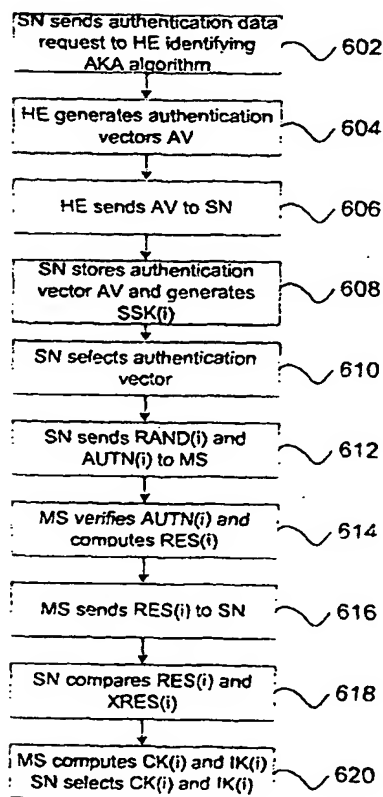
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(54) Title: CRYPTOGRAPHIC TECHNIQUES FOR A COMMUNICATIONS NETWORK



(57) Abstract: Techniques are described for enabling authentication (602) and/or key agreement (620) between communications network stations and service networks. The techniques described include negotiation and use of a cryptographic primitive (608) shared between a service network and a home environment of a station. The techniques described also feature a key usage indicator, such as a sequence number, maintained by the service network and a station. Comparison of the key usage indicators can, for example, permit efficient authentication of the service network.

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CRYPTOGRAPHIC TECHNIQUES
FOR A COMMUNICATIONS NETWORK

Technical Field

5 The present invention relates generally to cryptographic techniques for use in a communications network such as a wireless communications network.

Background Art

10 First generation wireless communications networks were based on analog technologies such as the Advanced Mobile Phone Service (AMPS). Second generation wireless communications networks introduced digital communications technologies such as the Global System
15 Mobile (GSM), IS-136 Time Division Multiple Access (TDMA), and IS-95 Code Division Multiple Access (CDMA). Authentication and Key Agreement (AKA) protocols were developed for first and second generation networks to prevent theft of cellular telephone service, to provide
20 subscriber voice privacy, and provide other security features.

FIG. 1 illustrates a typical cellular telephone or Personal Communication Services (PCS) network. A subscriber, using a Mobile Station (MS) 130 (e.g., a
25 cellular phone), can roam outside of the area covered by their Home Environment (HE) 110 network and obtain wireless communications service from a Serving Network (SN) 120. The HE 110 and SN 120 networks typically include a switch, base station, and other components
30 (not shown), as is known in the art. As is known in the art, the HE 110, SN 120, and MS 130 are controlled by software, firmware, and/or hardware instructions.

The MS 130 often features a removable Universal Subscriber Identity Module (USIM) that resides in the MS 130 to store subscriber information such as a subscriber's identity, secret key information, and so forth. To simplify descriptions herein, the USIM is considered part of MS 130. However, a subscriber can transfer their USIM into other MS-s 130 to obtain service.

An AKA protocol for second generation wireless communication networks provides MS 130 to SN 120 authentication. In a typical GSM system, the HE 110 and MS 130 share a common 128-bit secret key K. To enable roaming privacy and authentication, HE 110 passes an authentication vector including three pieces of cryptographic data to a SN 120. Each vector includes a random challenge, response, and privacy key.

When MS 130 requests service, SN 120 transmits the random challenge over the air to the MS 130. MS 130 combines the random challenge with the secret key K using a cryptographic primitive (e.g., a hash function) to generate the response. MS 130 transmits the response to SN 120 which compares the response value received from MS 130 with the response value provided by HE 110. If the response values are equal, SN 120 provides system access to MS 130. MS 130 also uses the random challenge and K to create a privacy key that is identical to the privacy key sent from HE 110 to SN 120 as part of the cryptographic triplet. With the same privacy key, SN 120 and MS 130 can securely communicate. In this scheme, the SN 120 need not implement a cryptographic primitive (e.g., a hash function).

A third generation AKA mechanism adopted by the Third Generation Project Partners (3GPP) enhances the original GSM AKA mechanism by enabling mutual authentication between SN 120 and MS 130. The 3GPP AKA
5 mechanism replaces the GSM crypto-triplet vector with a crypto-quintet authentication vector (AV) to facilitate MS/SN mutual authentication.

FIG. 2 illustrates formation of an AV by an HE 110. As shown, the AV includes five components concatenated
10 together: (1) the random challenge (RAND), (2) an expected response (XRES), (3) a cipher key (CK), (4) an integrity key (IK), and (5) an authentication token (AUTN). AUTN includes three components: (1) an exclusive-or of a sequence number (SQN) and anonymity
15 key (AK), (2) a MODE value, and (3) a message authentication code (MAC). The sequence number indicates the AVs position in a sequence of AVs. Functions f1 through f5 are derived using a cryptographic primitive shared between HE 110 and MS
20 130. Different values of primitive constants or parameters control which function, f1 through f5, the primitive provides.

When roaming, a MS 130 may be authenticated each time a MS 130 owner places a call. Thus, typically, an
25 HE 110 sends multiple AVs to SN 120 to enable multiple authentications between SN 120 and MS 130.

FIG. 3 illustrates SN 120 authentication in 3GPP AKA. To authenticate SN 120, the MS 130 and HE 110 keep track of counters SQN_{MS} and SQN_{HE} . When HE 110 generates
30 an AV, SQN_{HE} is incremented. MS 130 authentication of SN 120 is performed by ensuring that SQN in each new AV is greater than SQN in the previous AV. The MS 130 also

verifies that SQN_{HE} originated from the HE 110 by verifying the MAC in the AUTN.

It is possible for the SQN counter in HE 110 and MS 120 to lose synchronization. For this reason, the 3GPP AKA mechanism has SQN re-synchronization procedures. If K is reset or replaced for a particular USIM, SQN can be reset at the HE 110 and MS 130.

FIG. 4 illustrates the flow of a typical 3GPP AKA mechanism. When MS 130 requests service from SN 120, SN 120 sends (step 202) an authentication request to HE 130. Upon receiving the request associated with a particular MS 130, HE 110 generates (step 204) an array of AVs for that particular MS 130. HE 110 sends (step 206) the AVs to SN 120 which, in turn, stores (step 208) the AVs in its Visitor Location Register (VLR). SN 120 selects (step 210) the first sequential AV(i) (e.g., $i = 1$) and sends (step 212) $RAND(i)$ and $AUTN(i)$ to MS 130. MS 130 verifies (step 214) $AUTN(i)$ and computes $RES(i)$. If $SQN(i)$ is greater than SQN_{MS} , MS 130 successfully authenticates SN 120. MS 130 sends (step 216) $RES(i)$ to SN 120. SN 120 compares (step 218) $RES(i)$ with $XRES(i)$. If RES and $XRES$ are equal, SN 120 has successfully authenticated MS 130. Finally, MS 130 computes (step 220) $CK(i)$ and $IK(i)$ while SN 120 selects $CK(i)$ and $IK(i)$.

FIG. 5 illustrates a cryptographic key hierarchy of the 3GPP AKA mechanism. A secret key K is the root secret shared only between the HE 110 and MS 130. Whenever mutual authentication is performed, a cipher key (CK) is generated to facilitate voice and data privacy. Additionally, an integrity key (IK) is generated to facilitate message authentication.

The North American Telecommunications Industry Association (TIA) TR-45 standards group has based AKA on a shared secret between HE 110, SN 120, and MS 130. In a TR-45 cellular/PCS network, HE 110 sends Shared Secret Data (SSD) to SN 120 to enable MS 130 to SN 120 authentication. SSD is derived from an Authentication key (A-key), shared between HE 110 and MS 130 only. The A-key is analogous to the GSM secret key K. SSD consists of SSD-A, used for MS 130 challenge-response authentication, and SSD-B, used for SN/MS voice and data privacy. When MS 130 requests service from SN 120, HE 110 sends SSD to SN 120. With SSD, SN 120 can authenticate MS 130 until SSD is updated between HE 110 and MS 130.

Unlike a GSM network where SN 120 continuously requests new vectors of crypto-triplets to perform MS 130 authentication, SN 120 in a TR-45 network acquires unique SSD from HE 110 and uses SSD for the duration that MS 130 operates within the SN 120 area. Ideally, SSD update is performed between HE 110 and MS 130 after MS 130 leaves the SN 120 area to establish a new SSD, preventing SN 120 from knowing an SSD used by another service network. Unfortunately, many service providers do not update SSD frequently, allowing many service providers to know SSD-A which is the authentication secret for TR-45 cellular telephones.

The TIA TR-45 is considering adoption of the 3GPP AKA for TR-45 networks to support global harmonization of wireless communication standards. To retain the advantages of using a shared secret like SSD, the TR-45 is considering using the 3GPP IK key as SSD for third generation TR-45 wireless networks.

Additionally, the TR-45 is considering the adoption of the Long-term Enhanced Subscriber Authentication (LESA) AKA in which interlocking challenges provide mutual authentication between SN 120 and MS 130. In the
5 LESA AKA mechanism, SN 120 sends a random number R_N to MS 130. MS 130 generates a second random number R_M . MS 130 computes a response to SN 120 by combining R_N , R_M , and SSD in a cryptographic primitive. MS 130 sends the response and random number R_M to SN 120. With R_M , SN 120
10 computes the same response, authenticating MS 130. Then SN 120 computes a second response for MS 130 by combining R_M and SSD in the cryptographic primitive. SN 120 sends the second response to MS 130. MS 130 verifies the second response, authenticating SN 120.

15 Finally, 3GPP has considered an AKA mechanism similar to the LESA AKA, known as Authentication based on a Temporary Key (A-TK). The A-TK AKA mechanism uses a procedure of interlocking challenges between HE 110 and MS 130 to establish a temporary key (KT). Once KT
20 is established, SN 120 uses traditional challenge-response to authenticate MS 130. MS 130 authentication of SN 120, however, is not performed explicitly, but is implicitly achieved by the establishment of CK and IK based on random numbers provided by SN 120 and MS 130.

25

Disclosure of Invention

Techniques are described for enabling authentication, key agreement, and/or encrypted communication between communications network stations
30 and service networks. The techniques described herein can include the negotiation and use of a cryptographic primitive shared between a service network and a home

environment of a station. The techniques described also include use of a key usage indicator, such as a sequence number, maintained by the service network and a station. Comparison of the key usage indicators can, for example, permit efficient authentication of the service network by the station without undue burden on a home environment network of the station.

In general, in one aspect, the invention features a method for use in authenticating a service network to a station. The method includes storing a key at the service network and transmitting information to the station that enables the station to compute the key stored at the service network. The method also includes receiving a request for service at the service network from the station, adjusting a value corresponding to key usage, and transmitting information corresponding to the value to the station.

Embodiments may include one or more of the following features. The method may include receiving a vector of authentication information from the home environment network of the mobile station. The vector includes an indication of the vector's position in a sequence of vectors. The information transmitted to the station that enables the station to compute the key stored at the service network may include one or more portions of the received vector of authentication information. The received vector of authentication information can include the key stored by the service network. The method may further include computing, at the service network, the key stored by the service

network based on information included in the received vector.

Adjusting a value indicating use of the key can include incrementing a sequence number corresponding to
5 a number of times the key has been used. The method may further include using the key to compute a cipher key for encrypting communication between the service network and the station. The method may also include negotiating use of a cryptographic primitive between the
10 service network and the home environment network.

In general, in another aspect, the invention features a method for use in authenticating a service network to a station. The method includes computing a key, stored by the service network, based on information
15 received at the station from the service network. The station maintains an indicator of key usage. The method includes receiving at the station an indicator of key usage maintained by the service network and comparing the key usage indicator maintained by the service
20 network with the key usage indicator maintained by the station.

Embodiments may include one or more of the following features. The method may further include maintaining an authentication vector sequence number at
25 the station, receiving at the station from the service network an indication of an authentication vector sequence number maintained by the home environment network, and comparing the authentication vector sequence number maintained by the home environment
30 network with the received authentication vector sequence number maintained by the station. The method may include receiving from the service network

identification of a cryptographic primitive. The method may include using the key to compute a cipher key for encrypting communication between the service network and the station.

5 In general, in another aspect, the invention features a method for use in authentication in a communications network including a home environment network, a service network, and a station. The method includes determining at the home environment network a
10 cryptographic primitive offered by the service network and transmitting to the service network at least one vector of authentication information corresponding to a particular station.

 Embodiments may include one or more of the
15 following features. Determining may include receiving identification of the cryptographic primitive from the service network, for example, as a value of a MODE field. The vector of authentication information may include an indication of an authentication vector
20 sequence number maintained by the home environment network.

 In general, in another aspect, the invention features a method for use by a mobile station that can communicate with different service networks. The method
25 includes storing different sets of cryptographic information for the different respective service networks, selecting a set of cryptographic information for one of the service networks, and using the selected set of cryptographic information to communicate with the
30 service network.

 Embodiments may include one or more of the following. The sets of cryptographic information may

include a key shared by the station and the service network. The method may include computing the key shared by the station and the service network based on information received from the service network. The sets
5 of cryptographic information may include an indicator of usage of the key. Using the selected set of cryptographic information may include using the selected set of cryptographic information in encrypting communication between the station and the service
10 network.

In general, in another aspect, the invention features a method of handling authentication and key agreement in a system including a home environment network, a service network, and a mobile station in
15 which the home environment network and the mobile station share a secret key K. The method includes determining whether the home environment and the service network share a cryptographic primitive. If it is determined that the home environment and the service
20 network do not share a cryptographic primitive, the method handles authentication and key agreement between the mobile station and the service network using 3GPP (Third Generation Project Partners) AKA (authentication and key agreement). If it is determined that the home
25 environment and the service network share a cryptographic primitive, handling authentication and key agreement by computing a shared secret key (SSK), transmitting information from the service network to the station that enables the station to compute the SSK, and
30 replacing the use of K in the 3GPP AKA with SSK.

Advantages will become apparent in view of the following description, including the figures and the claims.

5 **Brief Description of Drawings**

FIG. 1 is a block diagram of a communications network according to the prior art;

FIG. 2 illustrates generation of an authentication vector according to the prior art;

10 **FIG. 3** illustrates authentication of a service network according to the prior art;

FIG. 4 is a flow-chart of an authentication and key agreement process according to the prior art;

FIG. 5 illustrates a cryptographic key hierarchy
15 according to the prior art;

FIG. 6 is a flowchart of an initial authentication and key agreement process used to generate a shared secret K;

FIG. 7 is a flowchart of a mutual authentication
20 mechanism using a shared secret K;

FIG. 8 illustrates generation of an authentication token;

FIG. 9 illustrates authentication of a service network using a temporary sequence number;

25 **FIG. 10** illustrates generation of a shared secret;

FIG. 11 illustrates a cryptographic key hierarchy;

FIG. 12 illustrates generation of a shared secret authentication vector by a home environment;

FIG. 13 illustrates a cryptographic key hierarchy;

30 **FIG. 14** illustrates a mobile station straddling bordering cells of different service networks; and

FIG. 15 is a flowchart of a mobile station process for handling communication with a service network.

Best Mode for Carrying Out the Invention

5 Described herein are techniques that can securely, efficiently, and robustly handle authentication and key agreement in a communications network such as a wireless communications network. In particular, the techniques described herein can enhance traditional 3GPP AKA by
10 giving service providers the option to use traditional 3GPP AKA or an optional AKA mechanism. The present invention is not limited to wireless applications, and can also be used in other networks such as electronic toll systems, internet access terminals, cable TV and
15 data networks, and other networks in which a service provider allows subscribers to use another service provider's network. For purposes of the following description, the techniques are described with respect to a wireless communications network. However, the
20 description should be understood as applying to other networks or devices, such as the ones discussed above.

In one aspect, the invention features an optional 3GPP AKA mechanism that can be used in conjunction with the traditional 3GPP AKA. In the optional 3GPP AKA, a
25 HE 110 and SN 120 share at least one common cryptographic primitive. For example, HE 110 and SN 120 may both use SHA-1 or MD-5 as a cryptographic hash function.

The optional 3GPP AKA can include procedures that
30 allow for primitive negotiation, for example, between the HE 110 and SN 120. For example, a one byte MODE field can store data identifying the AKA cryptographic

primitive or set of AKA cryptographic primitives offered by an HE 110, SN 120, or MS 120. For example, a MODE field value of "S" can represent a request for communication using a shared SHA-1 primitive. The SN
5 120 authentication data requests can also include a primitive version identifier.

As will be appreciated by those of skill in the art, a field other than the MODE field may be used to facilitate AKA primitive negotiation between elements of
10 the communication network. Additionally, as those of skill in the art will appreciate, a wide variety of alternate information exchanges can be used to negotiate a shared primitive. For example, either the HE 110 or SN 120 may initiate negotiation. Similarly, either the
15 HE 110 or SN 120 may initially identify the cryptographic primitive(s) it offers.

If HE 110 and SN 120 do not share a common AKA primitive (e.g., if HE 110 determines that it does not provide the primitive identified in an SN 120 request
20 for AVs), standard 3GPP AKA is performed instead of the optional 3GPP AKA mechanism described below. If HE 110 and SN 120 share a common AKA primitive, the optional 3GPP AKA mechanism, may be used to increase the efficiency of mutual authentication between the MS 130
25 and SN 120.

FIG. 6 illustrates the flow of an optional AKA mechanism that can reduce the amount of Authentication Vector (AV) traffic by establishing a Shared Secret K (SSK) between the MS 130 and SN 120 using one AV. As
30 shown, when MS 130 requests service from SN 120, SN 120 sends (step 602) an authentication request to HE 130 indicating that a common primitive is available. Upon

receiving the request associated with a particular MS 130 and noting the indication of a shared primitive (e.g., HE 110 offers the same primitive as indicated by the MODE field), HE 110 generates (step 604) at least
5 one AV associated with that particular MS 130. After generating (step 604) the AV, the HE 110 sends (step 606) the AV to SN 120. SN 120 stores the AV in its Visitor Location Register (VLR) and generates (step 608) SSK(i). After initial communication, communication
10 between the SN 120 and MS 130 will depend on both computing the same SSK(i).

After selecting (step 610) an AV(i), SN 120 sends (step 612) RAND(i) and AUTN(i) of AV(i) to MS 130. MS 130 verifies AUTN(i) and computes (step 614) RES(i) (see
15 FIG. 3). If SQN(i) is greater than SQN_{MS}, MS 130 successfully authenticates SN 120. MS 130 sends (step 616) RES(i) to SN 120. SN 120 then compares (step 618) RES(i) with XRES(i). If RES and XRES are equal, SN 120 has successfully authenticated MS 130. Finally, MS 130
20 computes CK(i) and IK(i) while SN 120 selects (step 620) CK(i) and IK(i).

After establishing SSK and performing the initial AKA, the standard AKA protocol between SN 120 and MS/USIM 130 is modified by replacing K_i with SSK_i for AKA
25 calculations between the SN 120 and MS 130 for the duration of MS roaming. The protocol is further modified by using a Temporary SQN (TSQN) established between the SN 120 and MS/USIM 130 for the duration of MS 130 roaming in the SN 120 network area.

30 FIG. 7 illustrates how subsequent authentications are performed between SN 120 and MS 130, for example, in response to a MS 130 request for service from SN 120.

SN 120 generates (step 702) $RAND(i)$ and generates
TAUTN(i) using $SSK(i)$ (see FIG. 8). SN 120 sends (step
704) $RAND(i)$ and TAUTN(i) to MS 130, for example, with
MODE = SHA-1. MS 130 verifies (step 706) TAUTN(i) and
5 computes RES(i) (see FIG. 9). If $TSQN_{SN}(i)$ is greater
than $TSQN_{MS/USIM}$, MS 130 successfully authenticates SN 120.
MS 130 sends (step 708) RES(i) to SN 120. SN 120
compares (step 710) RES(i) with XRES(i). If RES and
XRES are equal, SN 120 has successfully authenticated MS
10 130. MS 130 computes (step 712) $CK(i)$ and $IK(i)$. SN
120 computes (step 714) $CK(i)$ and $IK(i)$.

Just as SQN_i uniquely increments for a K_i , $TSQN_i$
uniquely increments for an SSK_i . Thus for a unique SSK,
the MS 130 maintains a uniquely incrementing TSQN to
15 facilitate mutual authentication between the MS 130 and
SN 120. While TSQN increments each time the same SSK is
used for communication between an SN and MS, TSQN
increments for a relatively short period of time
compared with SQN, lessening the chance mis-
20 synchronization. Additionally, TSQN need not impact the
maintenance of SQN within the HE 110 and MS/USIM 130.
TSQN can automatically reset when a new SSK (associated
with a particular SN 120 is formed. This approach can
eliminate the TR-45 problem of having to update SSD.

25 As described above, TSQN is a sequence number.
However, other values indicating key usage may be
featured. For example, adjusting the value may feature
decrementing instead of incrementing a numeric value.
Additionally, the value need not be restricted to
30 numbers but may instead feature a character or boolean
value.

A HE/SN pair, sharing a common primitive, can choose to utilize this scheme if they desire. However, even if HE 110 and SN 120 share a common AKA primitive, the HE 110 can utilize the standard 3GPP AKA mechanism
5 and pass multiple AVs to SN 120.

The HE 110 may pass one or more AVs to SN 120 with the MODE value indicating standard 3GPP AKA. The SN 120, however, after the initial standard AKA setup, can use a common AKA primitive MODE value (e.g. SHA-1) to
10 notify the MS 130 to use SSK and TSQN when utilizing the modified 3GPP AKA. Prior to initiating the optional AKA scheme, the SN 120 may determine if the MS 130 supports (e.g., includes instructions for) the optional scheme, for example, based on MS 130 identification information
15 transmitted by the MS 120. Additionally, the MS 130 can transmit a message to the SN 120 declining use of the optional scheme, for example, if the MS 130 does not provide the primitive identified by the SN 120 in the MODE field.

FIG. 10 illustrates an example of SSK generation. As shown, SSK can be generated using IK and RAND where f_3 is the generating function (e.g. $SSK = f_3_{IK}(RAND)$). SSK may also be generated using a new function f_6 derived from the shared cryptographic primitives(s) if
25 desired.

FIG. 11 illustrates a cryptographic key hierarchy for the optional 3GPP AKA mechanism. A secret key K is the root secret shared between the HE 110 and MS 130. When mutual authentication is first performed between SN
30 120 and MS 130, a CK is generated to facilitate voice and data privacy and an IK is generated to facilitate message authentication. SSK can be derived from IK

using function f3. For all subsequent SN 120 network accesses, CK and IK are derived from SSK.

FIG. 12 illustrates a different optional AKA mechanism. As shown, SSK may be generated using a new
5 function f6 (e.g. $SSK = f6_K(RAND)$). When using the new function, SSK can be generated by HE 110. HE 110 can include the generated SSK in the AV. With SSK included in the AV, the AV is defined as Shared Secret AV (SSAV). A SN 120 receiving SSAV can simply extract SSK instead
10 of independently computing SSK. The MS 130, however, still independently determines SSK from AV information transmitted by SN 120 to the MS 130.

After initial MS/SN mutual authentication and SSK generation, the SN 120 and MS/USIM 130 use SSK and TSQN
15 for subsequent authentications as shown in Figure 7. Resynchronization of TSQN is not necessary because SN 120 can query HE 110 for a new SSAV, perform standard 3GPP AKA and establish a new SSK with a TSQN reset. The SN 130 may request multiple AVs from the HE 110
20 initially to allow for new SSK formation and TSQN reset.

FIG. 13 illustrates the cryptographic key hierarchy when SSK is formed by HE 110 using RAND and K. Although SSAV is larger than AV, HE 110 and SN 120 traffic is reduced in comparison to the original 3GPP AKA mechanism
25 because only one SSAV is sent to SN 120 for roaming authentication. By generating SSK from RAND and K, instead of from RAND and IK, AKA mechanism security is improved. Thus, SSK can be derived from IK for improved efficiency or from K for improved security.

30 FIG. 14 illustrates another aspect of the invention that provides support for border cell operations. As shown, the MS 130 can store different cryptographic

elements (e.g., SSK/TSQN pairs) for different SNs 120. By storing multiple SSK/TSQN pairs with each pair associated with a different SN 120, the MS 130 can straddle the border between multiple systems without
5 requiring VLR-to-VLR AV sharing, SSD sharing, or SSD update.

As shown in FIG. 14, MS 130 straddles between areas served by two different serving networks. MS 130 uses SSK_{SN-A} for service from serving network A (SN-A) and
10 SSK_{SN-B} for service from serving network B (SN-B). The MS 130 may store identification of a SN and the respective SSK/TSQN pair being used. Thereafter, the 130 may identify the SN providing service to retrieve the appropriate pair.

SSK freshness depends on the SN 120 VLR and MS 130 rules. For example, the SN 120 may chose to store SSK for up to a week of inactivity. The MS 130 may store multiple SSK/TSQNs in a queue (five pairs or more) using first-in-first-out (FIFO). This technique may be ideal
20 for travelers moving between multiple systems and countries within a brief period of time. In the event the MS 130 deletes SSK_{SN-A} before SN-A deletes SSK_{SN-A}, the MS will recognize that SN-A is attempting the optional 3GPP AKA (e.g., MODE = SHA-1), issue a user
25 authentication reject, and await standard 3GPP AKA to establish a new SSK with SN-A.

FIG. 15 is a flowchart of a process for using cryptographic data associated with different cells. As shown, a MS stores (step 1502) cryptographic data, such
30 as SSK/TSQN pairs, for different service networks. After determining (step 1504) a SN providing service,

the MS can access and use the associated cryptographic data, for example, for authentication and encryption.

The techniques described above can, potentially, offer significant benefits for networks such as 3GPP and TR-45 (3GPP2) networks. For example, the techniques can allow for standard 3GPP AKA or modified 3GPP AKA at a service provider's discretion. The techniques can offer mutual authentication based on a publicly scrutinized cryptographic primitive. Potentially, techniques can reduce HE/SN AV traffic when a common AKA primitive is shared between HE and SN. The techniques can reduce the probability of SQN re-synchronization problem by using TSQN. The techniques can also reduce the need for SSD update in TR-45 networks, can reduce the vulnerability of fixed SSD by ensuring new SSK formation between MS and SN, can reduce cryptographic export/import concerns for the United States and other countries interested in adopting TR-45 standards, and can reduce the need for VLR-to-VLR AV sharing, SSD sharing, and SSD update for border cell operations.

Claims:

1. A method for use in authenticating a service network to a station, the station having a home environment network, the method comprising:
5 storing a key at the service network;
transmitting information to the station from the service network that enables the station to compute the key stored at the service network;
10 receiving a request for service at the service network from the station;
adjusting a value corresponding to key usage; and
transmitting information corresponding to the value to the station.

15 2. The method of claim 1,
further comprising receiving a vector of authentication information from the home environment network of the station, the vector including an
20 indication of the vector's position in a sequence of vectors; and
wherein transmitting information to the station that enables the station to compute the key stored at the service network comprises transmitting portions of
25 the received vector of authentication information.

3. The method of claim 2, wherein the received vector of authentication information comprises the key stored by the service network.

30 4. The method of claim 2, further comprising computing at the service network the key stored by the

service network based on information included in the received vector.

5 5. The method of claim 1, wherein adjusting a value indicating use of the key comprises incrementing a sequence number corresponding to a number of times the key has been used.

10 6. The method of claim 5, wherein the value comprises a TSQN (Temporary Sequence Number).

15 7. The method of claim 1, wherein the station comprises a cellular phone; and the service network and home environment networks comprise cellular networks.

20 8. The method of claim 1, further comprising using the key to compute a cipher key for encrypting communication between the service network and the station.

25 9. The method of claim 1, further comprising negotiating use of a cryptographic primitive between the service network and the home environment network.

30 10. The method of claim 1, further comprising transmitting a challenge to the station; receiving a challenge response from the station; and comparing the received challenge response with an expected response.

11. The method of claim 1, further comprising:
computing the key stored by the service network at
the station;
receiving the information indicating the value
5 corresponding to key usage at the station; and
comparing the received value with a value
corresponding to key usage maintained by the station.
12. A method for use in authenticating a service
10 network to a station, the station having a home
environment network, the method comprising:
receiving information at the station from the
service network;
computing a key based on the information received
15 at the station from the service network, the computed
key also being stored by the service network;
maintaining an indicator of key usage at the
station;
receiving at the station an indicator of key usage
20 maintained by the service network; and
comparing the key usage indicator maintained by the
service network with the key usage indicator maintained
by the station.
- 25 13. The method of claim 12, further comprising:
maintaining an authentication vector sequence
number at the station;
receiving at the station from the service network
an indication of an authentication vector sequence
30 number maintained by the home environment network; and
comparing the authentication vector sequence number
maintained by the home environment network with the

received authentication vector sequence number
maintained by the station.

14. The method of claim 13, further comprising
5 receiving from the service network identification of a
cryptographic primitive.

15. The method of claim 12, wherein
the station comprises a cellular phone; and
10 the service network and home environment network
comprise cellular networks.

16. The method of claim 12, further comprising:
using the key to compute a cipher key for
15 encrypting communication between the service network and
the station.

17. The method of claim 12, further comprising:
receiving a challenge from the service network;
20 determining a challenge response; and
transmitting the challenge response to the service
network.

18. The method of claim 12, wherein maintaining an
25 indicator of key usage at the station comprises
maintaining a key sequence number counter.

19. A method for use in authentication in a
communications network including a home environment
30 network, a service network, and a station, the method
comprising:

determining at the home environment network a cryptographic primitive offered by the service network; and

based on the determined cryptographic primitive,
5 transmitting to the service network at least one vector of authentication information corresponding to a particular station.

20. The method of claim 19, wherein determining
10 comprises receiving identification of the cryptographic primitive from the service network.

21. The method of claim 20, wherein the identification comprises a value of a MODE field.
15

22. The method of claim 19, wherein the vector of authentication information comprises an indication of an authentication vector sequence number maintained by the home environment network.
20

23. The method of claim 22, wherein the vector of authentication information comprises a challenge and an expected response.

25 24. A method for use by a mobile station that can communicate with different service networks, the method comprising:

storing different sets of cryptographic information for the different respective service networks;

30 selecting a set of cryptographic information for one of the service networks; and

using the selected set of cryptographic information to communicate with the service network.

25. The method of claim 24, wherein the sets of
5 cryptographic information comprise a key shared by the station and the service network.

26. The method of claim 25, further comprising
10 computing the key shared by the station and the service network based on information received from the service network.

27. The method of claim 25, wherein the sets of
15 cryptographic information comprise an indicator of usage of the key.

28. The method of claim 27, wherein the indicator of usage comprises a sequence number.

20 29. The method of claim 27, further comprising:
receiving from the service network an indicator of key usage; and

comparing the received indicator of key usage with the indicator of key usage included in the selected set
25 of cryptographic information.

30. The method of claim 25, wherein using the selected set of cryptographic information comprises using the selected set of cryptographic information to
30 authenticate the service network.

31. The method of claim 25, wherein using the selected set of cryptographic information comprises using the selected set of cryptographic information in encrypting communication between the station and the service network.

32. A method of handling authentication and key agreement in a system including a home environment network, a service network, and a mobile station, the home environment network and the mobile station sharing a secret key K, the method comprising:

determining whether the home environment and the service network share a cryptographic primitive;

if it is determined that the home environment and the service network do not share a cryptographic primitive, handling authentication and key agreement between the mobile station and the service network using 3GPP (Third Generation Project Partners) AKA (authentication and key agreement); and

if it is determined that the home environment and the service network share a cryptographic primitive, handling authentication and key agreement by:

computing a shared secret key (SSK);

transmitting information from the service network to the station that enables the station to compute the SSK; and

replacing the use of K in the 3GPP AKA with SSK.

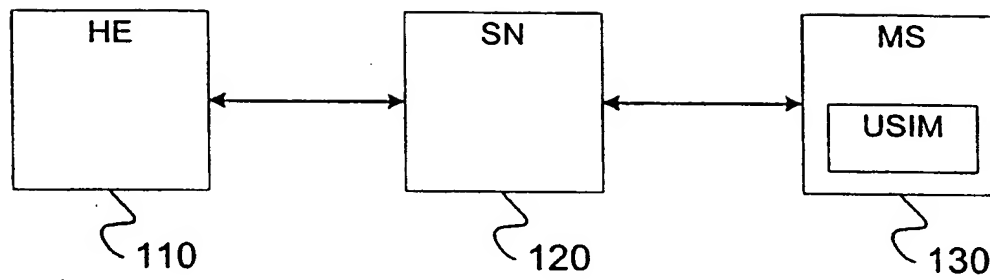
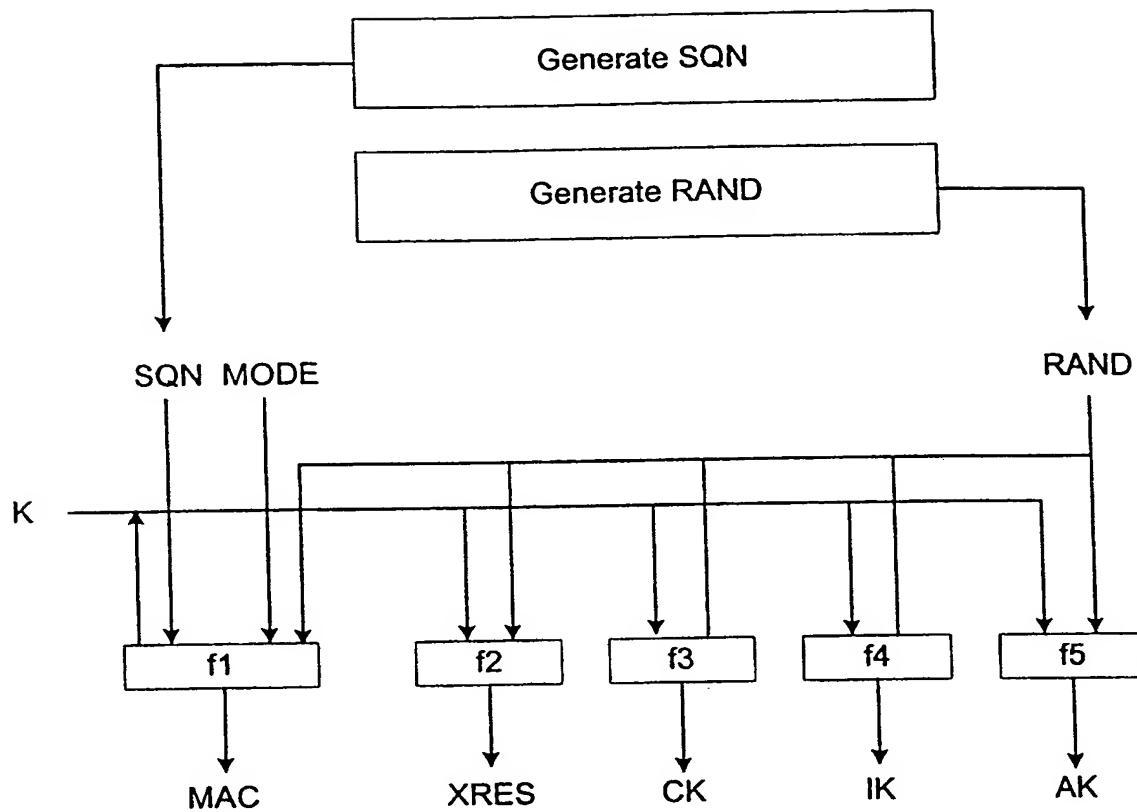
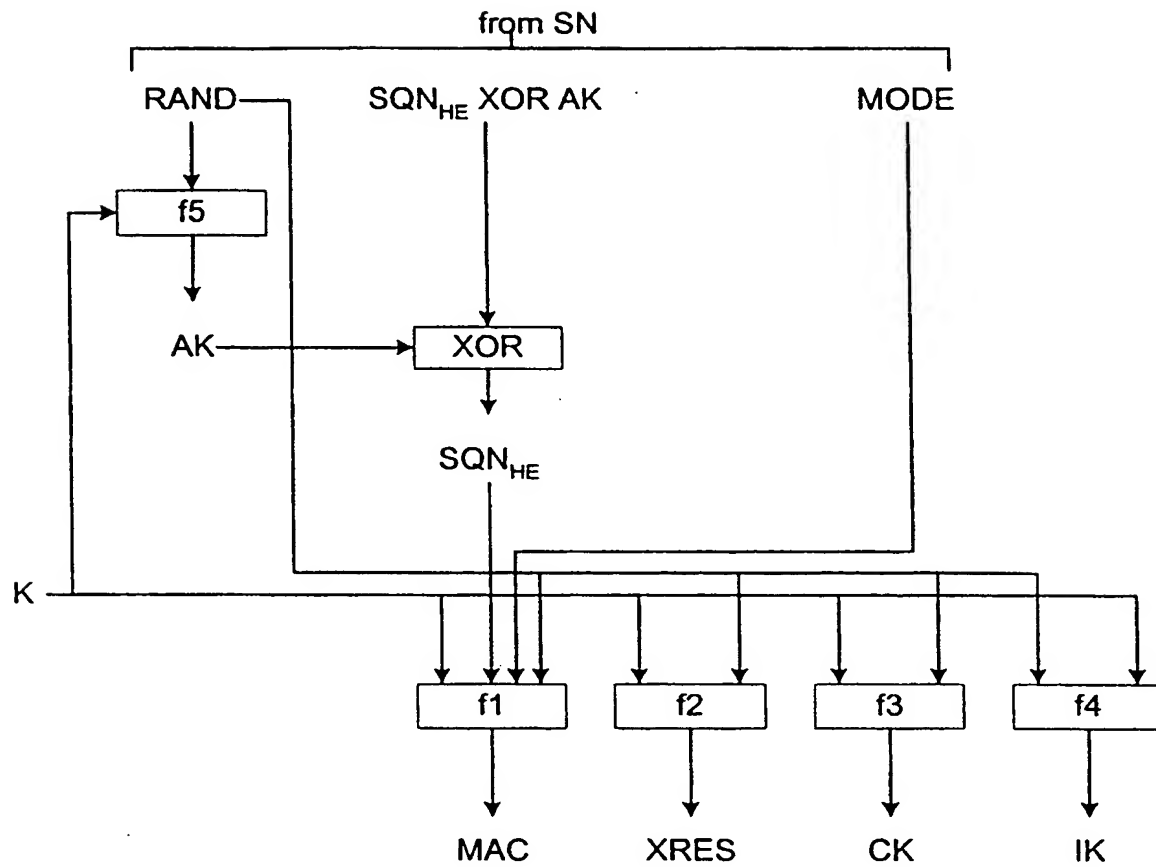


FIG. 1/15
(Prior Art)



$$\text{AUTN} := \text{SQN XOR AK} \parallel \text{MODE} \parallel \text{MAC}$$
$$\text{AV} := \text{RAND} \parallel \text{XRES} \parallel \text{CK} \parallel \text{IK} \parallel \text{AUTN}$$

FIG. 2/15
(Prior Art)



Verify MAC = XMAC
Verify SQN_{HE} > SQN_{USIM/MS}

FIG. 3/15
(Prior Art)

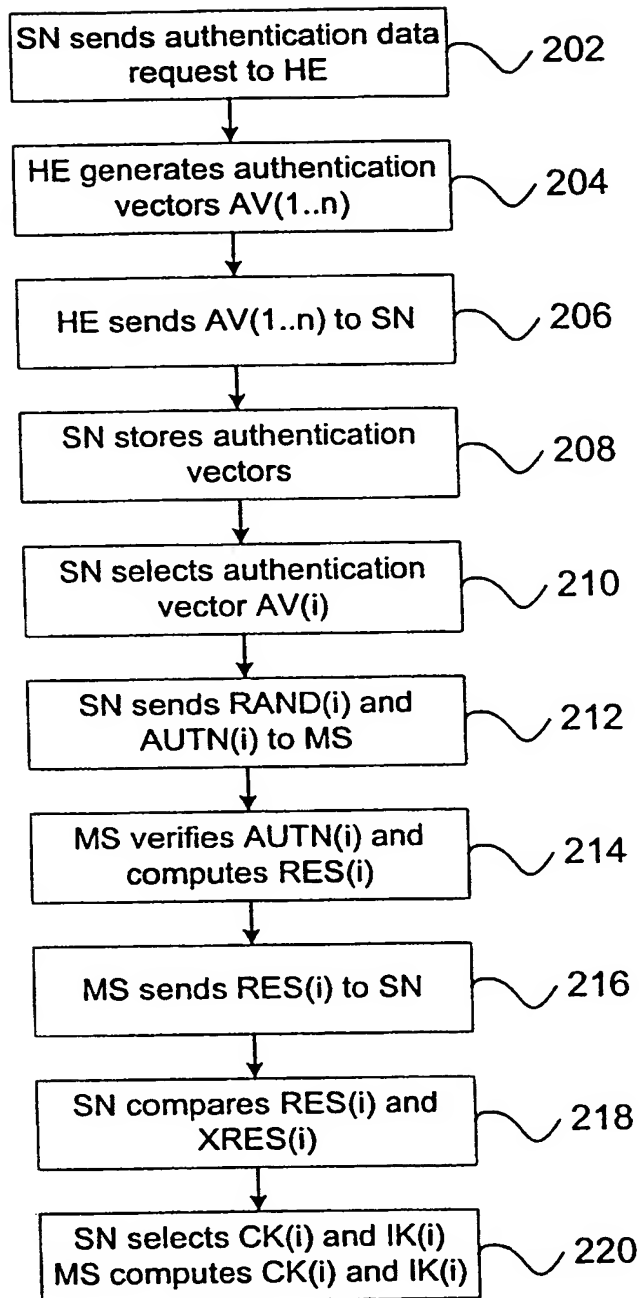


FIG. 4/15
(Prior Art)

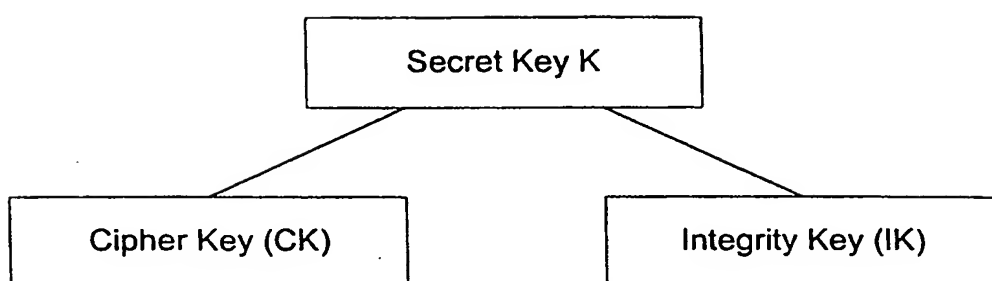
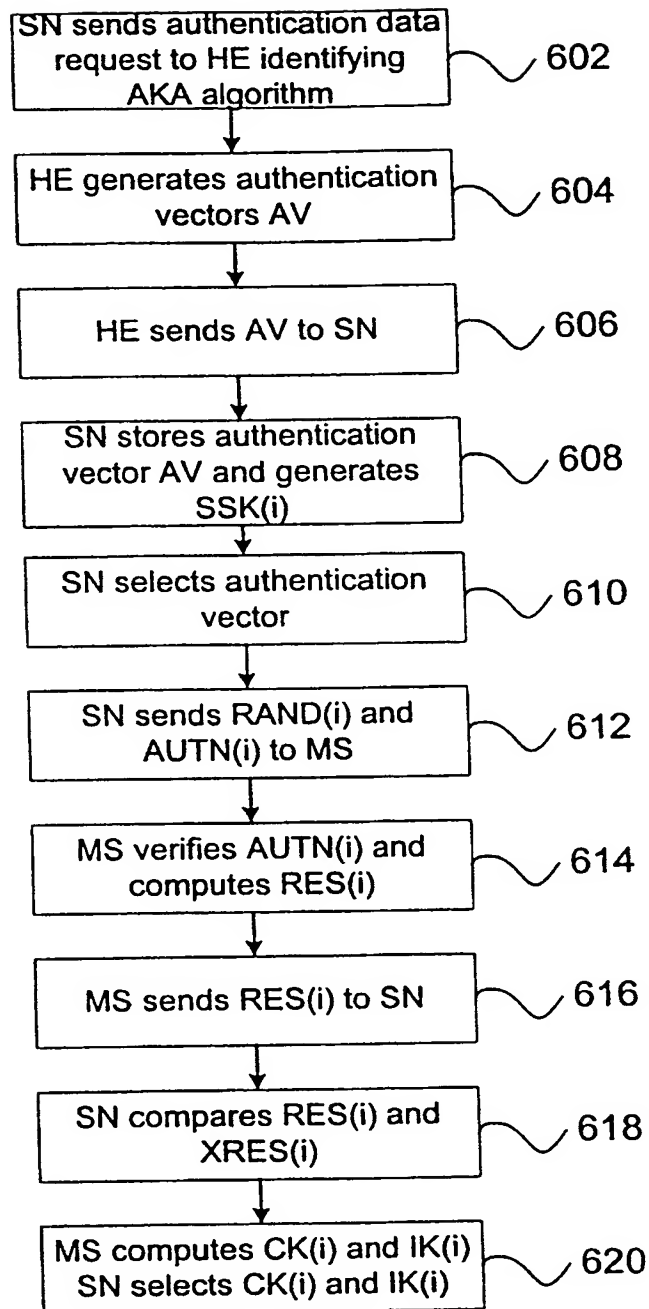
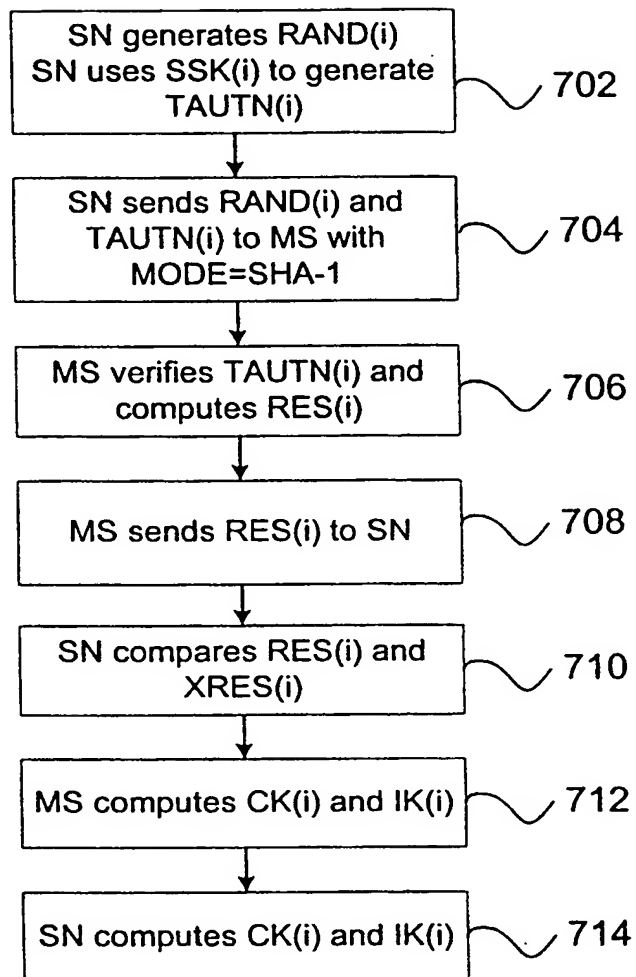
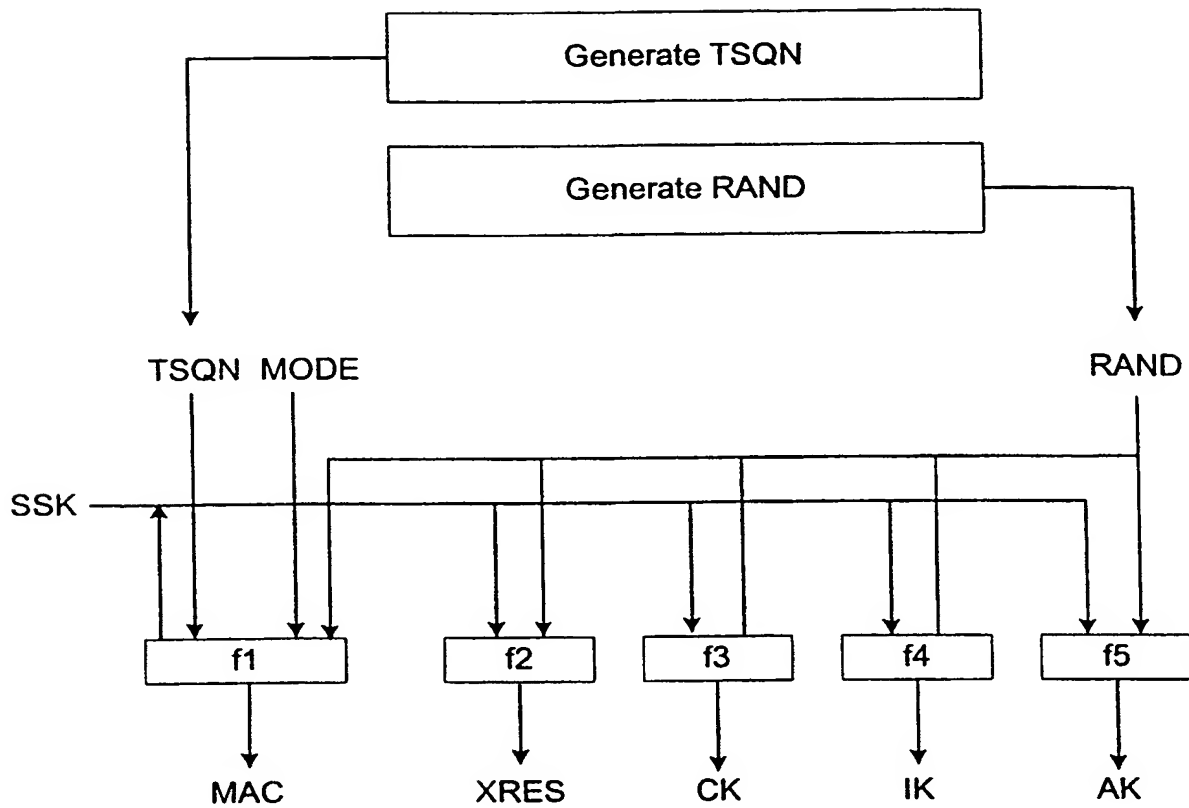


FIG. 5/15
(Prior Art)

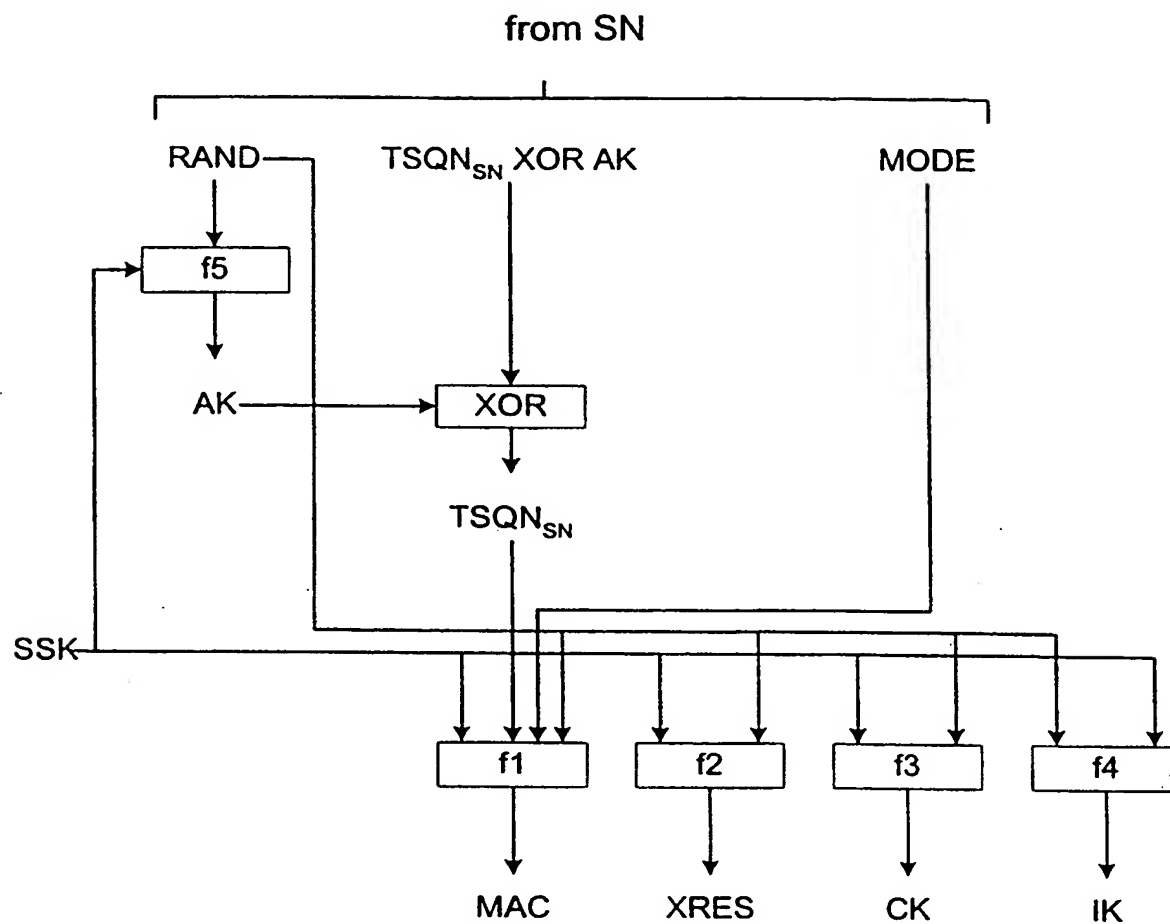
**FIG. 6/15**

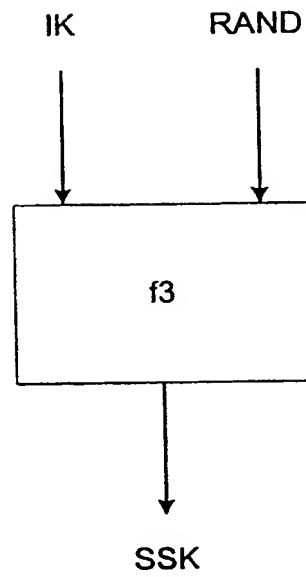
**FIG. 7/15**

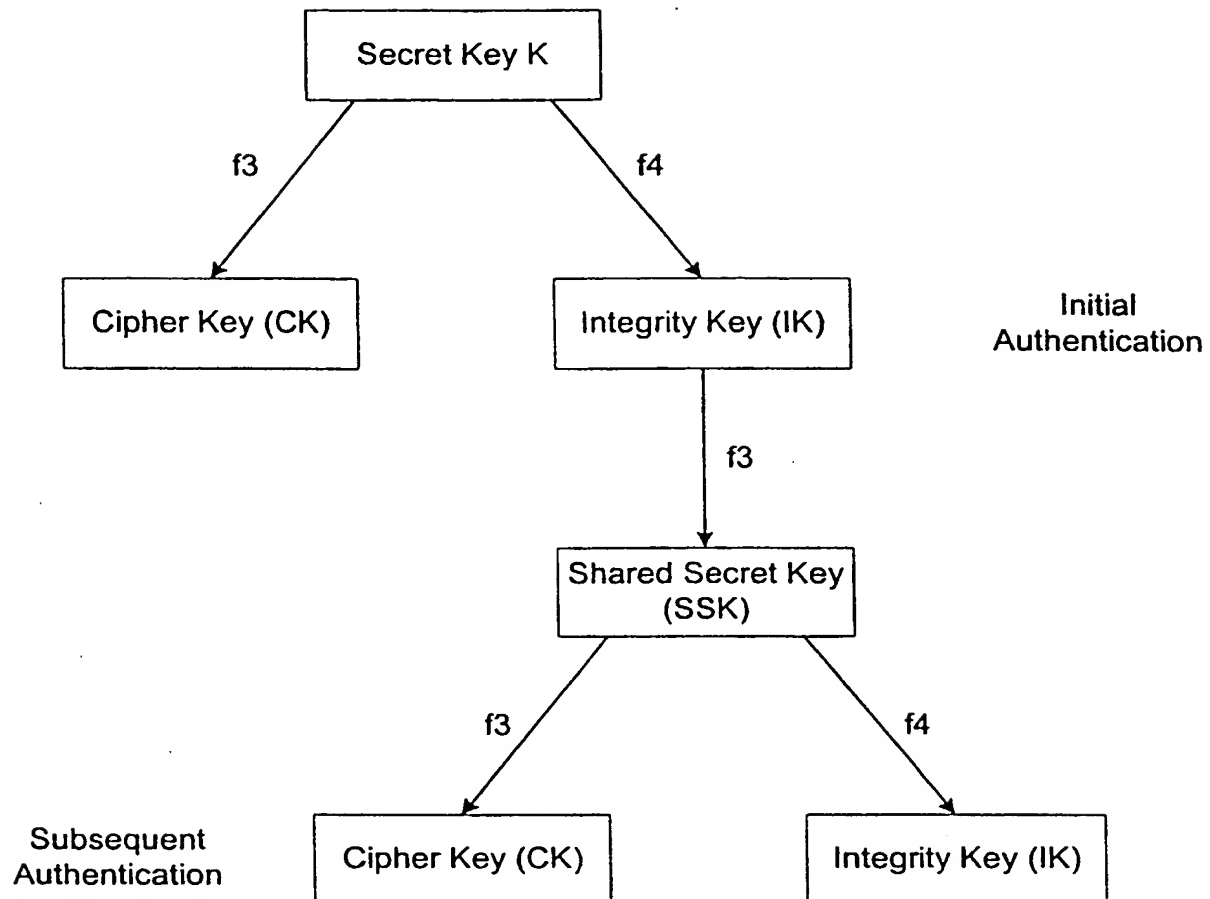


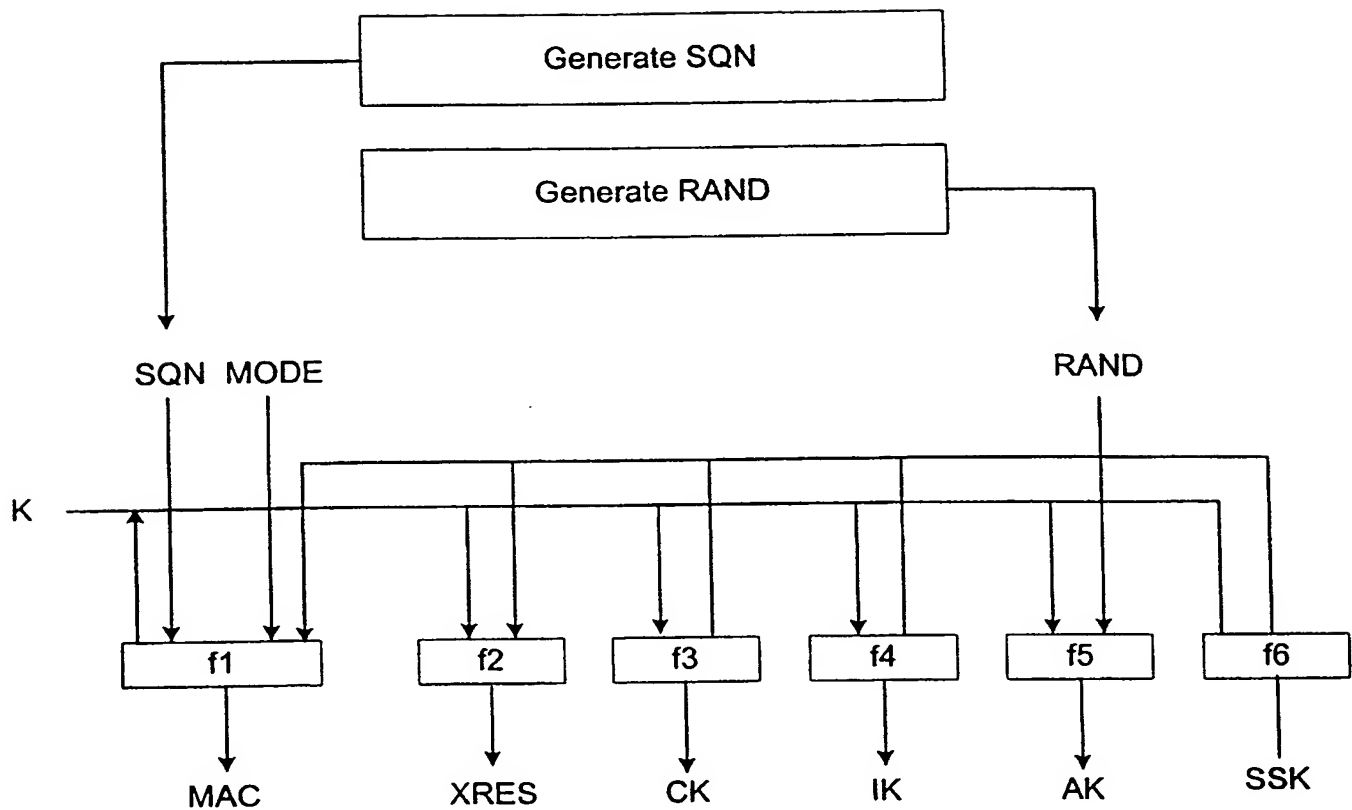
$\text{TAUTN} := \text{TSQN XOR AK} \parallel \text{MODE} \parallel \text{MAC}$

FIG. 8/15

**FIG. 9/15**

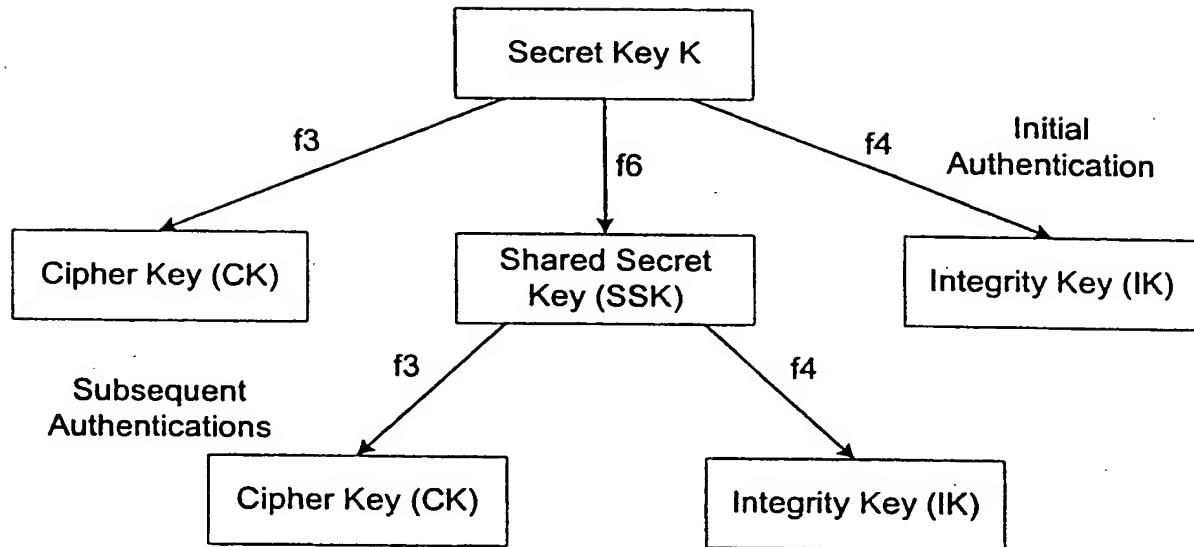
**FIG. 10/15**

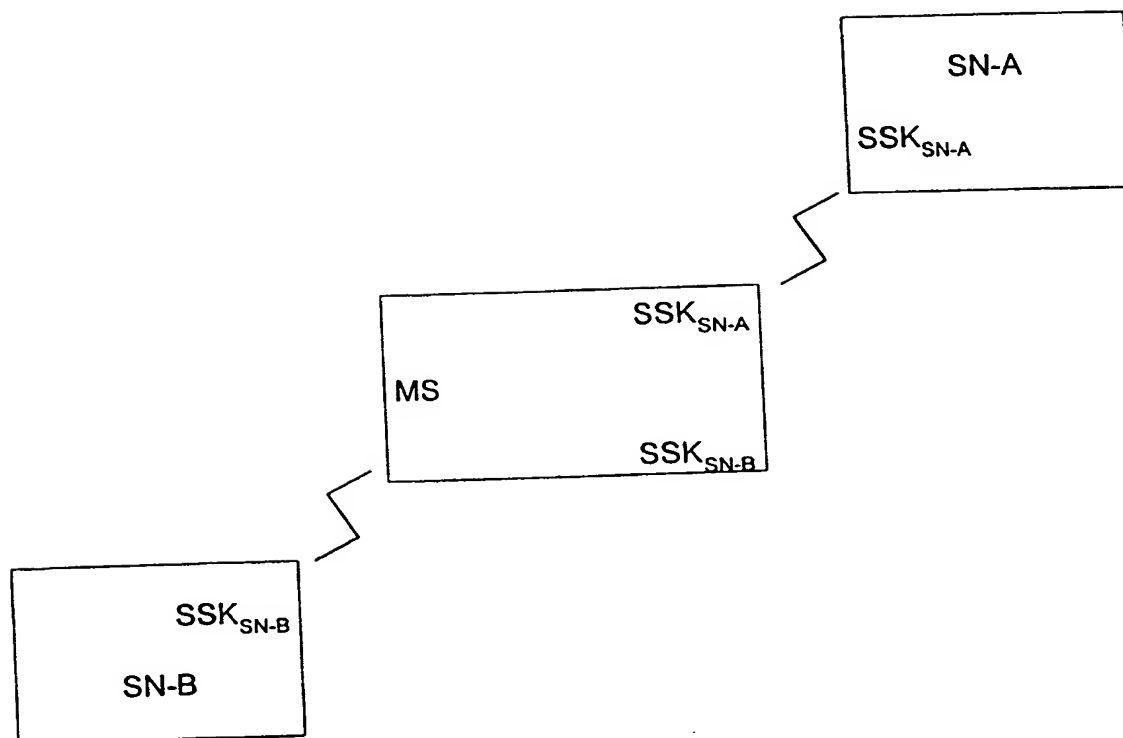
**FIG. 11/15**

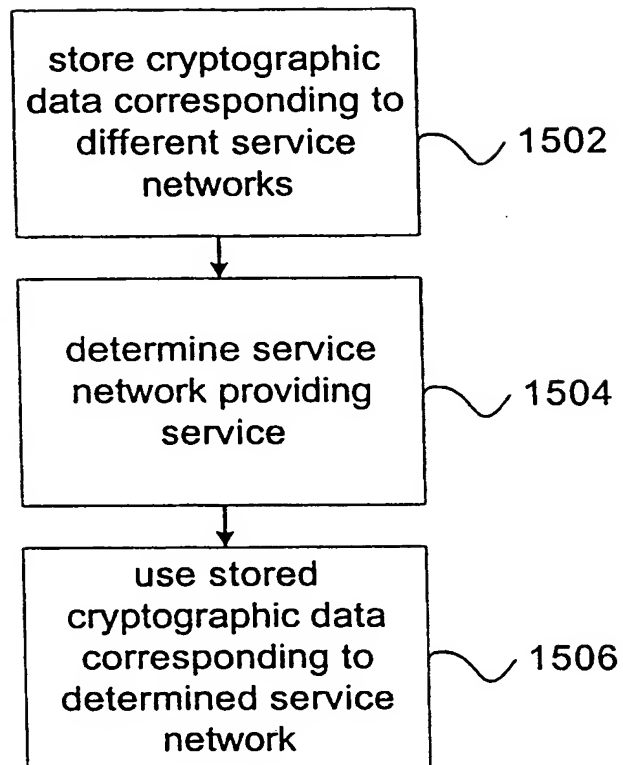


$$\text{AUTN} := \text{SQN XOR AK} \parallel \text{MODE} \parallel \text{MAC}$$
$$\text{SSAV} := \text{RAND} \parallel \text{XRES} \parallel \text{CK} \parallel \text{IK} \parallel \text{SSK} \parallel \text{AUTN}$$

FIG. 12/15

**FIG. 13/15**

**FIG. 14/15**

**FIG. 15/15**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US00/31103

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : H04L 9/00

US CL : 380/247, 280; 713/168, 171

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 380/247, 280; 713/168, 171

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EAST, search terms: "key usage," "cell\$4," "shared secret key," "authentication near2 vector"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,993,069 A (MATYAS et al) 12 February 1991 (12.02.1991), columns 1 and 2.	1-6, 8, 9, 11-14, 16, 18-22, 24-32

Y		7, 10, 15, 17, 23
Y,P	US 5,991,407 A (MURTO) 23 November 1999 (23.11.1999), see column 2, lines 9-17	7, 10, 15, 17, 23
A	US 4,941,176 A (MATYAS et al) 10 July 1990 (10.07.1990), see abstract	1-32
A	US 5,604,802 A (HOLLOWAY) 18 February 1997 (18.02.1997), column 9, lines 38-53.	1-32
A	US 4,888,800 A (MARSHALL et al) 19 December 1989 (19.12.1989), see column 2, lines 35-43.	1-32

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

07 March 2001 (07.03.2001)

Date of mailing of the international search report

30 MAR 2001

Name and mailing address of the ISA/US

Commissioner of Patents and Trademarks

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